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H04B 1/707

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INT CL^7 H04B 1/707
Online:WPI,EPODOC,JAPIO

(54) Abstract Title
Rake receiver

(57) A rake receiver comprises a plurality of fingers e.g. 31, each finger having an output; and a combiner 38, which is connected to receive signals provided on the outputs of the fingers and to provide a combined output signal in response thereto. Each finger includes a respective mixer 51 arranged to mix a received signal with a locally generated pseudo-random noise code, which is provided by a further mixer 56. Each finger includes a first detector (46 fig 3) which detects a parameter such as the signal to interference ratio (SIR) of the signal downstream of the mixer 56 over a first relatively long period of time and provides an output signal in response thereto. A control means (47), controls the finger 31 to track a multipath component of the received signal on the basis of the first detector output signal. A second detector 48 detects the SIR over a second relatively short period of time, and provides an output to a second control means 49, which switches 39 the output to the combiner 38 off, if any sample falls below a threshold 59 SIR.

The receiver may have a second set of fingers which receive a code-multiplexed pilot signal such as a CPICH channel in the UMTS system and switch the output of the data signal in dependence on variations in the CPICH channel.

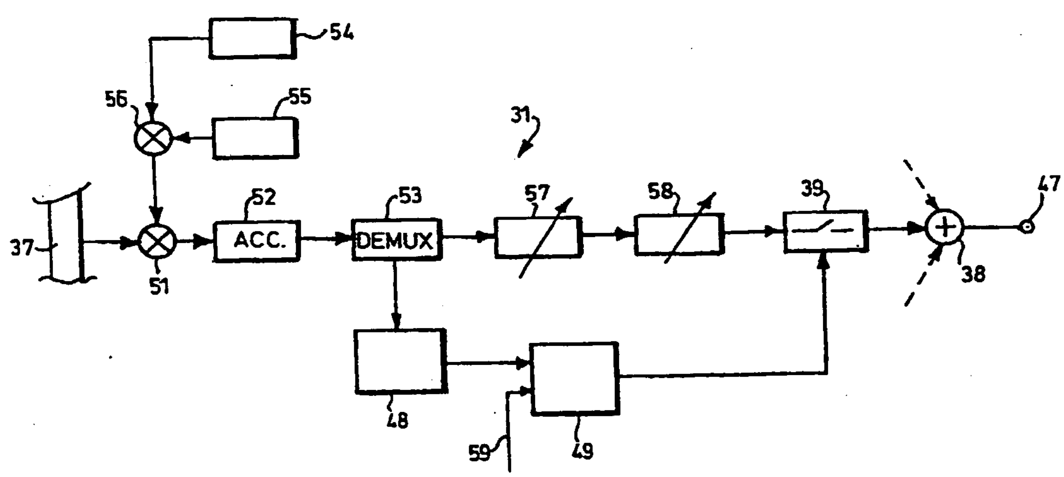

Fig.4.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

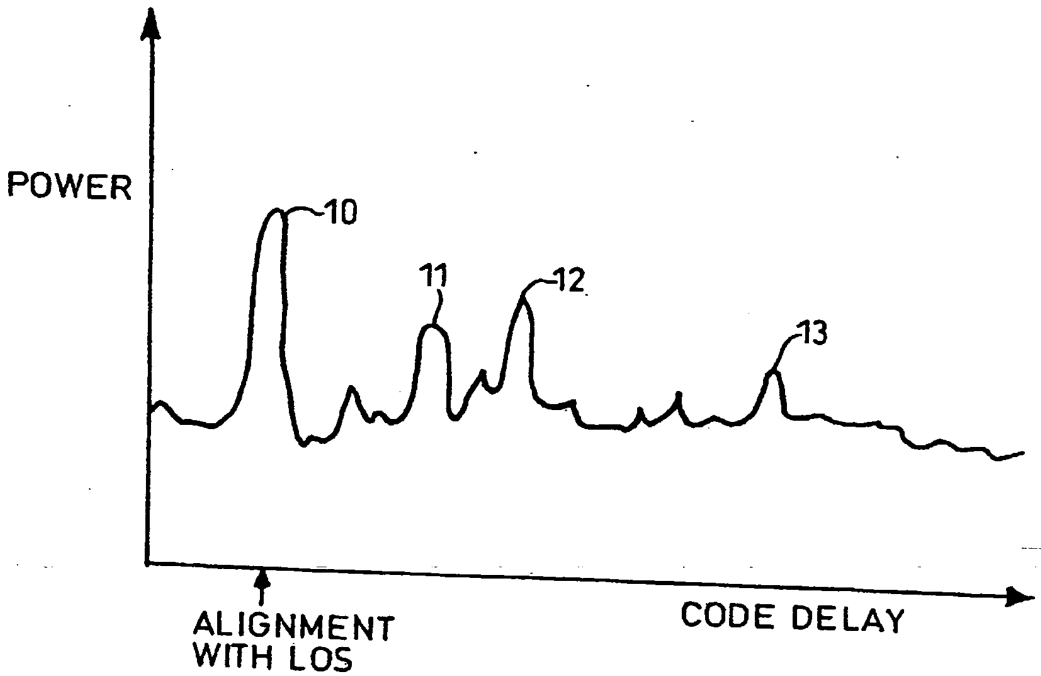
POWER
10
11
12
13
ALIGNMENT
WITH LOS
CODE DELAY

Fig.1.

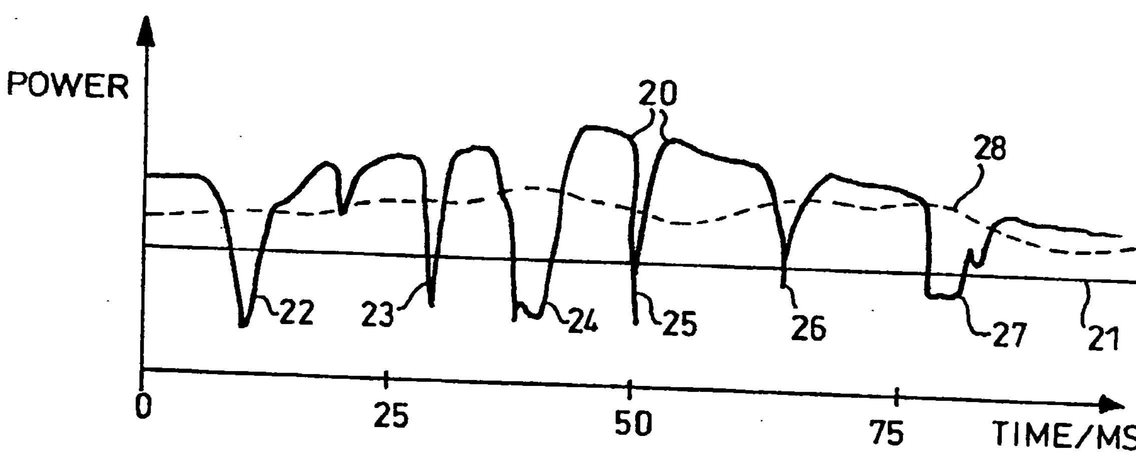
POWER
20
28
22
23
24
25
26
27
21
0
25
50
75
TIME/MS

Fig.2.

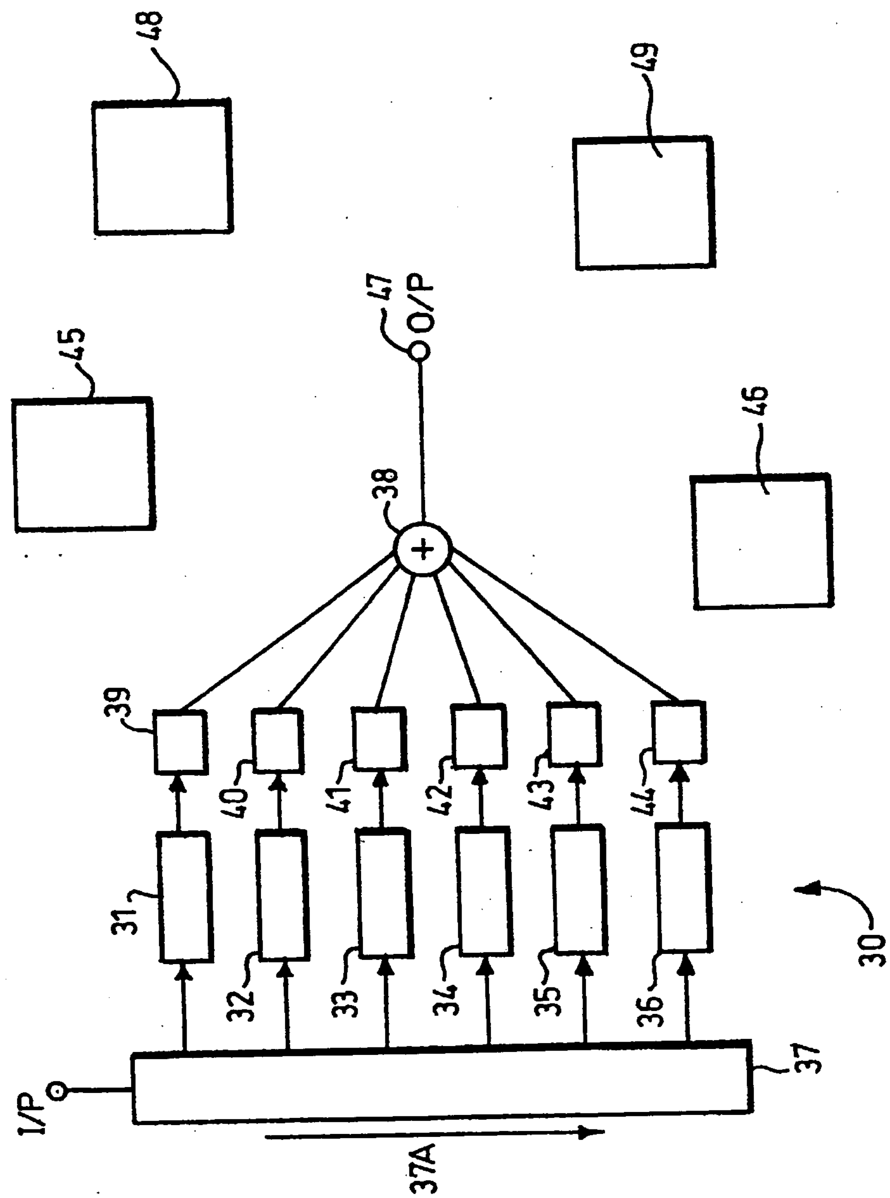

Fig.3.

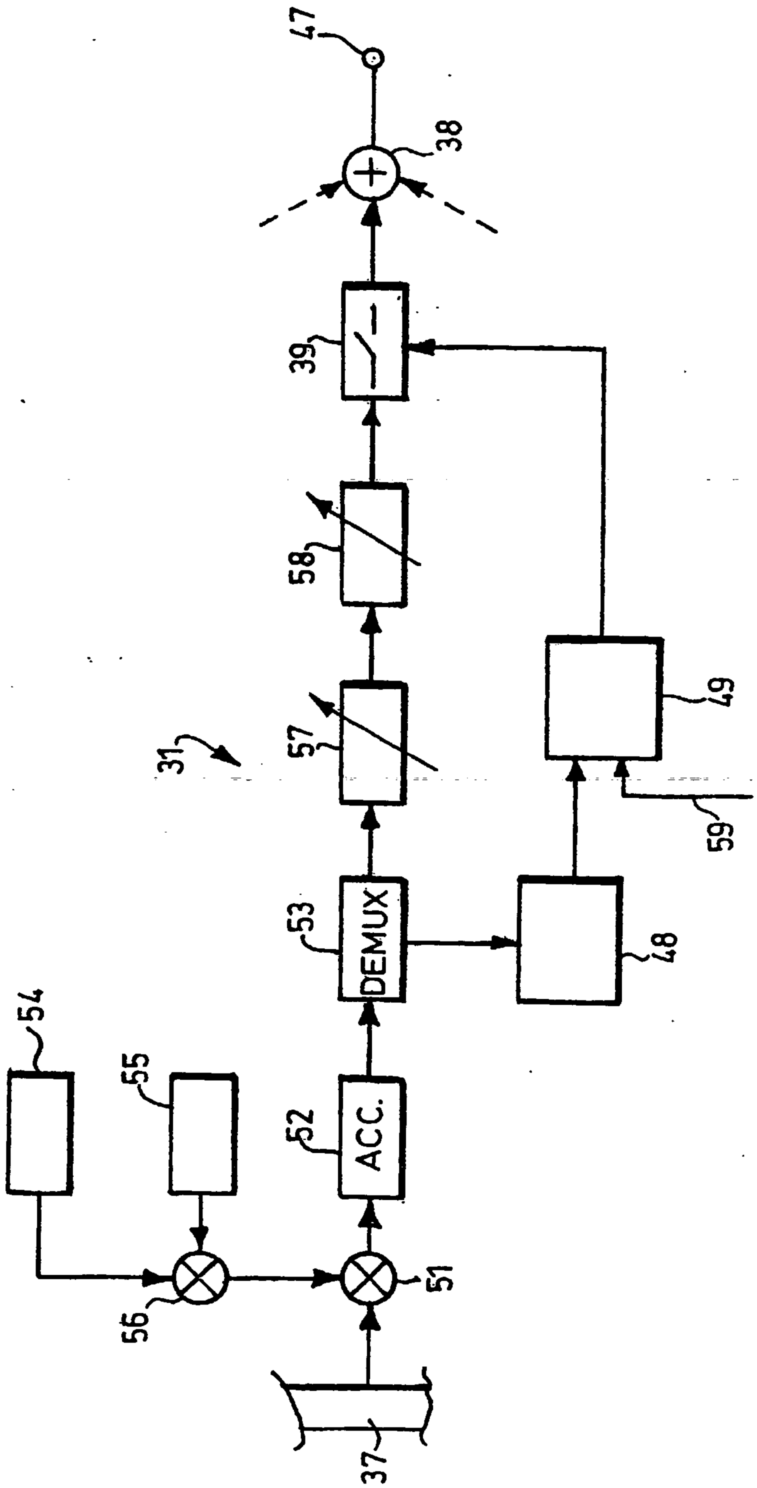

Fig.4.

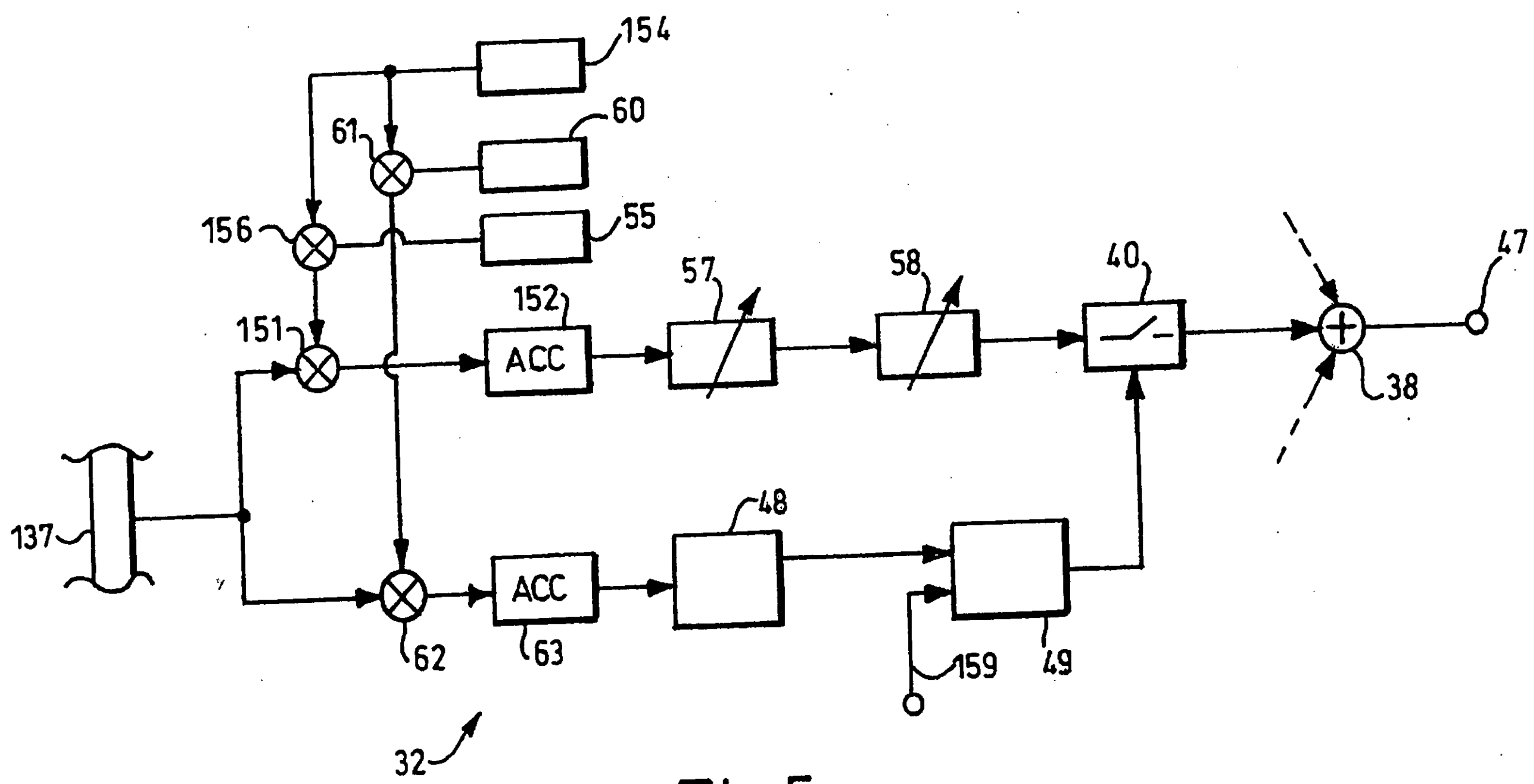
154
60
61
156
55
151
152
ACC
57
58
40
47
38
137
48
ACC
62
63
159
49
32

Fig.5.

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A RAKE RECEIVER AND A METHOD OF OPERATING A RAKE RECEIVER

This invention relates to a rake receiver, and to a method of operating a rake receiver.

It is common in wideband code division multiple access (W-CDMA) radio receivers to use a rake receiver to process a received signal. A rake receiver comprises a number of correlators, typically four correlators, which are arranged in parallel with their outputs being applied to an adder. The output of the adder is the output signal for the rake receiver. Each correlator can be called a 'finger', and each finger is independently controllable. Since it is necessary to generate a pseudo-random noise (PN) code at the same frequency and phase as the code which is modulated onto the received signal to achieve correlation with a line-of-sight (LOS) ray, it is possible to isolate delayed multipath rays by mixing a delayed version of the code with the received signal. The code delay must be equal to the time delay between the LOS ray and the multipath ray for correlation to occur. In practice, due to receiver limitations and the effects of noise, a characteristic such as that shown in Figure 1 may be obtained.

In Figure 1, amplitude is plotted against code delay for a signal which is received over a short period in time. The LOS ray 10 is clearly visible as the strongest, since it has the largest amplitude. Multipath rays 11, 12, 13 are also visible at various places along the code delay axis (or code space), each having an amplitude independent to the others. Although not visible in this figure, the signal corresponding to each ray has its own carrier phase. Each finger of the rake receiver is controlled to follow a ray 10-13 of the received signal. Usually, one finger follows the LOS ray 10, and the other fingers each follow a multipath ray 11-13. Often, however, the LOS 10 ray is not sufficiently strong, in which case each finger may follow a different multipath ray. A finger includes a mixer and a delay element which operate in such a way that a correlated signal is provided. The carrier phase of the correlated signal is detected by a carrier phase detector and brought to an arbitrary value, which is the same value for each finger, and the amplitude of the signal is detected by a detector and then adjusted according to an

algorithm. The signals from all the fingers are then added by the adder, thereby obtaining efficient signal reception from the received signal. The rake receiver, in effect, 'rakes' the code space for relevant rays, brings them into line with each other, in time and carrier phase, and then sums them. A rake receiver provides a significant increase in signal-to-noise ratio (SNR) compared to a receiver which operates only on the LOS 10 ray or on a multipath ray 11-13.

As the receiver moves relative to the base station, the characteristic shown in Figure 1 changes in a number of ways. The multipath rays 11-13 move along the code space, one way or the other, as the difference in the lengths of the signal paths change relative to the LOS path. The carrier phase of the signals also changes over time, albeit more slowly. Most significantly, superposition causes the power of the signals to rise and fall by very significant amounts, with the rate and frequency of the power changes being dependent particularly on the dynamics of the propagation channel.

The rise and fall of signal power is a widely recognised phenomenon. A typical signal power versus time plot is shown in Figure 2 for a receiver moving rapidly, for example in a vehicle, in a high-building-density urban environment.

Referring to Figure 2, signal power 20 can be seen to vary with time, the power mostly being above the level of a noise floor 21, but dipping below the noise floor at six time intervals 22 to 27. The time intervals 23, 25 and 26 are fairly short-lived, but the time intervals 22, 24 and 27 are more lengthy.

A conventional rake receiver may include means for measuring the average signal power for each finger over a period of about 10 ms for the Universal Mobile Telephone System (UMTS), and control means to control that finger to continue tracking its ray on the basis of the average signal power. The average power of the signal 20 is shown as the dotted line 28. It will be appreciated that the average power (which is calculated frequently) is affected by the time intervals 22-27, but in this case the average power remains a reasonable distance above the noise floor 21. The finger therefore continually processes the received signal, and provides its output to the combiner. This

period of time, and providing a first output signal in response thereto; controlling the corresponding one of the first plurality of fingers to track a component of the received signal on the basis of the first output signal; detecting a second parameter of the output signal of the mixer over a second period of time which is shorter than the first period of time, and providing a second output signal in response thereto; and controlling a switch interposed between the mixer of the corresponding one of the first plurality of fingers and the combiner in response to the second output signal.

In accordance with a fourth aspect of the invention, there is provided a method of operating a rake receiver having a plurality of fingers, each finger having an output, the method comprising: summing, in a combiner, signals provided on the outputs of the fingers to provide a combined output signal, locally generating a pseudo-random noise code; mixing, in a respective mixer for each finger, a received signal with the pseudo-random noise code, and in at least one finger of the receiver: detecting a first parameter of a signal downstream of the mixer over a first period of time, and providing an output signal in response thereto; controlling the finger to track a component of the received signal on the basis of the first output signal; detecting a second parameter of the downstream signal over a second period of time which is shorter than the first period of time, and providing a second output signal in response thereto; and controlling a switch interposed between the mixer and the combiner in response to the second output signal.

Using this invention, it is possible to construct a rake receiver in which a finger continues to track a component of the received signal on the basis of a parameter, for example its average power, but varies the contribution the finger makes to the output of the rake receiver on the basis of the or another parameter of the signal over a shorter period of time than that used as the basis for the tracking decision. This allows a rake receiver to be constructed which shows an improved signal reconstruction, in terms of SNR or signal-to-interference ratio (SIR) in particular, whilst requiring relatively little extra receiver complexity.

Embodiments of the present will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a plot of code delay versus time for a CDMA signal received in a multipath environment;

Figure 2 shows a plot of signal power versus time for a rapidly moving CDMA receiver;

Figure 3 shows schematically part of a rake receiver according to this invention; and

Figures 4 and 5 show schematically parts of rake receivers according to alternative embodiments of the invention.

Figure 3 shows part of a rake receiver 30, the rake receiver comprising first to sixth fingers 31 to 36, each connected to a respective output of a tapped delay line 37. A received signal is applied to each of the fingers 31 to 36 via the tapped delay line 37, although each finger receives the received signal at a different delay. The fingers 31 to 36 are controlled to be moved up and down the outputs of the tapped delay line 37 in order to track respective components, or rays, of the received signal. The delay of the received signal is increased by the delay line 37 in the direction of the arrow 37A. Outputs of the fingers 31 to 36 are connected to a combiner 38 via respective switches 39 to 44.

Each finger 31 to 36 respectively includes, in sequence, a mixer 51, an accumulator 52, an amplitude adjuster 57 and a carrier phase adjuster 58 (as is described below with reference to Figures 4 and 5), as is conventional. A first detector 45 has a respective input connected to the output of each of the accumulators 52 of the fingers 31 to 36. The first detector 45 is arranged to detect or estimate the SIRs of the signal provided of the output of each of the accumulators over a first relatively long period of time during reception of a time-multiplexed pilot signal, and to provide SIR estimate output signals in response thereto. On the basis of these SIR estimation signals, a first controller 46,

period following the pilot signal transmission period. When the SIR estimation signals do not exceed the threshold signal, the controller 49 causes the switch 39 to be held open for the duration of the successive slot. The controller 49 effects control of the switch every slot.

To summarise, this embodiment provides a rake receiver comprising a plurality of fingers 31 to 36, each finger having an output; and a combiner 38, which is connected to receive signals provided on the outputs of the fingers and to provide a combined output signal in response thereto. Each finger 31 to 36 includes a respective mixer 51 arranged to mix a received signal with a locally generated pseudo-random noise code, which is provided by a further mixer 56. At least one finger 31 of the receiver includes a first detector 46 which detects a first parameter (the SIR) of a signal downstream of the mixer 56 over a first period of time and provides an output signal in response thereto; first control means 47, which is arranged to control the finger 31 to track a component of the received signal on the basis of the first detector output signal; a second detector 48, which detects a second parameter of the signal downstream of the mixer over a second period of time which is shorter than the first period of time, and provides a second detector output signal in response thereto; and second control means 49, which is arranged to control a switch 39 in response to the second detector output signal.

It is currently proposed for the UMTS for each base station to transmit a continuous pilot signal (a data stream consisting of all logic ones) on a dedicated pilot channel, called a CPICH channel, having a unique channel-specific OVSF code, which is modulated onto the received signal at the transmitter (not shown). This allows hardware in a radiotelephone to track continuously signals received over the CPICH channel, to make measurements thereof and to infer, from the measurements, the nature of the channel and therefore how signals are propagated over the channel. Since data channels occupy the same bandwidth as the CPICH pilot channel, characteristics of the data channels can be determined without measurement of signals received over the data channels. It is proposed for the transmitter power of data channels to be controlled by the receiver (base station or radiotelephone) which receives the data channels.

However, CPICH channels will be received by all radiotelephones in communication with the base station, and will therefore be transmitted at a constant power level.

Figure 5 shows the finger 32 in a rake receiver forming part of a radiotelephone operating to receive a code-multiplexed pilot signal, such as a CPICH channel. In Figure 5, the finger 32 includes a CPICH OVSF code generator 60 and a mixer 61, which mixes the output of the CPICH OVSF code generator 60 with the output of a pseudo-random code generator 154, which corresponds to the generator 54. The resulting signal is mixed with the signal provided by a delay line 137, equivalent to the delay line 37, by a further mixer 62, which is in parallel with a mixer 151, equivalent to the mixer 51. A second accumulator 63 is connected to receive signals passed from the further mixer 62. The second detector 48 is connected to receive signals passed from the second accumulator 63, and to estimate the SIR thereof as with the Figure 4 embodiment. An accumulator 152, equivalent to the accumulator 52, in effect accumulates data signals, whilst the accumulator 63 accumulates pilot signals. Since the propagation channel for the pilot signals is the same as the channel for the data signals, control of the switch 40 by the second controller 49 effects connection of the carrier phase adjuster 58 to the combiner 38 only when the SIR of the data signals is sufficiently high.

The rake receiver can be viewed as a first plurality of fingers, which fingers process data signals, and a second plurality of fingers which correspond one-to-one with the first plurality of fingers. Fingers of the second plurality receive only CPICH signals.

To summarise, this embodiment provides a rake receiver comprising a first plurality of fingers, being the parts of the fingers 31 to 36 which provide signals to the switches 39 to 44 via the amplitude and carrier phase adjusters, and a combiner 38, which is arranged to sum the outputs of the fingers of the first plurality to provide a data-carrying output signal. Also provided is a second plurality of fingers, being the parts of the fingers 31 to 36 which provide signals to the second detector 48 and which therefore correspond one-to-one with ones of the first plurality of fingers. Each of the second plurality of fingers are arranged to process a pilot signal having a known data sequence

and each of the fingers of both the first and the second pluralities include a respective mixer 151, 62 etc. which is arranged to mix a received signal with a locally-generated pseudo-random noise code, i.e. fingers of the first plurality mix the received signal with a code provided by the mixer 156 and fingers of the second plurality mix the received signal with a code provided by the mixer 61. At least one of the second plurality of fingers, such as the part of the finger 32, has associated with it the first detector 46, which detects a first parameter (such as the SIR) of a signal downstream of its respective mixer 151 over a first period of time, and provides an output signal in response thereto; the first control means 47, which are arranged to control the finger 32 to track a component of the received signal on the basis of the first detector output signal; the second detector 48, which detects a second parameter of the signal downstream of the mixer over a second period of time which is shorter than the first period of time, and provides a second detector output signal in response thereto; and the second control means 49, which is arranged to control the switch 40 interposed between the mixer 151 and the combiner in response to the second detector output signal.

Although a hardware implementation of the invention is preferred, the invention may also be carried out in software.

Claims

1. A rake receiver comprising: a first plurality of fingers; a combiner arranged to sum the outputs of the fingers of the first plurality to provide a data carrying-output signal; and a second plurality of fingers, each of the second plurality of fingers corresponding one-to-one with ones of the first plurality of fingers, each of the second plurality of fingers being arranged to process a signal having a known data sequence; each of the fingers including a respective mixer arranged to mix a received signal with a locally generated pseudo-random noise code; at least one of the second plurality of fingers having associated therewith: a first detector, for detecting a first parameter of a signal downstream of the respective mixer over a first period of time, and for providing an output signal in response thereto; first control means arranged to control the corresponding one of the first plurality of fingers to track a component of the received signal on the basis of the first detector output signal; a second detector for detecting a second parameter of the signal downstream of the mixer over a second period of time which is shorter than the first period of time, and for providing a second detector output signal in response thereto; and second control means arranged to control a switch interposed between the mixer of the corresponding one of the first plurality of fingers and the combiner in response to the second detector output signal.

2. A rake receiver comprising a plurality of fingers, each finger having an output; and a combiner connected to receive signals provided on the outputs of the fingers and to provide a combined output signal in response thereto, each finger including: a respective mixer arranged to mix a received signal with a locally generated pseudo-random noise code, at least one finger of the receiver including: a first detector for detecting a first parameter of a signal downstream of the mixer over a first period of time and for providing an output signal in response thereto; first control means arranged to control the finger to track a component of the received signal on the basis of the first detector output signal; a second detector for detecting a second parameter of the signal downstream of the mixer over a second period of time which is shorter than the first period of time, and for providing a second detector output signal in response thereto;

and second control means being arranged to control a switch interposed between the mixer and the combiner in response to the second detector output signal.

3. A receiver as claimed in claim 2, further comprising a third detector arranged to detect time multiplexed signals of known data sequence on the received signal, and to control the second control means on the basis of the second detector output signal only when signals of known data sequence are detected as being received.

4. A receiver as claimed in any preceding claim, in which the first and second parameters are signal-to-interference ratios, or signal powers, or any combination thereof.

5. A receiver as claimed in any preceding claim, in which the ratio of the duration of the second period of time to the first period of time is between 1 to 2 and 1 to 50.

6. A receiver as claimed in claim 5, in which the ratio of the duration of the second period of time to the first period of time is between 1 to 10 and 1 to 30.

7. A method of operating a rake receiver having a first plurality of fingers, the method comprising:

summing, in a combiner, the outputs of the fingers of the first plurality to provide a data carrying-output signal;

providing a second plurality of fingers corresponding one-to-one with ones of the first plurality of fingers,

processing a signal having a known data sequence in each of the second plurality of fingers;

locally generating a pseudo-random noise code;

mixing, in a respective mixer in each of the fingers, a received signal with the pseudo-random noise code; and

in at least one of the second plurality of fingers:

detecting a first parameter of a signal downstream of the respective mixer over a first period of time, and providing a first output signal in response thereto;

controlling the corresponding one of the first plurality of fingers to track a component of the received signal on the basis of the first output signal;

detecting a second parameter of the output signal of the mixer over a second period of time which is shorter than the first period of time, and providing a second output signal in response thereto; and

controlling a switch interposed between the mixer of the corresponding one of the first plurality of fingers and the combiner in response to the second output signal.

8. A method of operating a rake receiver having a plurality of fingers, each finger having an output, the method comprising:

summing, in a combiner, signals provided on the outputs of the fingers to provide a combined output signal,

locally generating a pseudo-random noise code;

mixing, in a respective mixer for each finger, a received signal with the pseudo-random noise code, and

in at least one finger of the receiver:

detecting a first parameter of a signal downstream of the mixer over a first period of time, and providing an output signal in response thereto;

controlling the finger to track a component of the received signal on the basis of the first output signal;

detecting a second parameter of the downstream signal over a second period of time which is shorter than the first period of time, and providing a second output signal in response thereto; and

controlling a switch interposed between the mixer and the combiner in response to the second output signal.

9. A method as claimed in claim 8, further comprising detecting time multiplexed signals of known data sequence on the received signal, and controlling the switch on the basis of the second detector output signal only when signals of known data sequence are detected as being received.

10. A rake receiver substantially as herein before described with reference to or as shown in Figure 3 and either Figure 4 or Figure 5 of the accompanying drawings.

The Patent Office

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Application No: GB 0022582.1
Claims searched: 1-10

Examiner: B.J.SPEAR
Date of search: 19 March 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): H4P (PAN, PDCSL)

Int Cl (Ed.7): H04B 1/707

Other: Online: WPI, EPODOC,JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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